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Institut national de recherche en hydrologie

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ABSTRACT

The Hydrology chapter in the annual Canadian Geophysical Bulletin consists of contributions from the seven national correspondents of the International Association of Scientific Hydrology Commissions. These commissions cover Surface Water, Ground Water, Snow and Ice, Continental Erosion, Remote Sensing and Data Transmission, Water Quality and Water Resource Systems. The combined submission from the National Hydrology Research Institute to all these correspondents is contained in this report. It covers research activities by institute staff during 1988.

RÉSUMÉ

SURFACE

WATER

CANADIAN GEOPHYSICAL BULLETIN

HYDROLOGY RESEARCH IN CANADA

1988

Organization National Hydrology Research Institute

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Researcher(s)

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S. Fogarasi	306-975-5758

Description of research

EVALUATION OF THE CRAE MODEL FOR EVAPORATION AND EVAPOTRANSPIRATION

A co-operative field study was conducted in 1986 and 1987 to evaluate the Complementary Relationship Areal Evapotranspiration Model (CRAE) under various land-use conditions at three sites in Alberta: irrigated cereal, natural grassland and, dryland cereal. It was found that CRAE evapotranspiration was up to 34% greater than the observed; slope aspect and elevation influence evapotranspiration; and, the model is very sensitive to dewpoint temperature.

Suggested for inclusion in the report of:

- Surface Water ☒
- Groundwater ☐
- Snow and Ice ☐
- Continental Erosion ☐
- Remote Sensing and Data Transmission ☐

NOTE: Water Quality and Water Resource Systems interests should be sent to one of these five correspondents.

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A. Wankiewicz	306-975-5757

Description of research

LAND DRAINAGE MODELLING

The elements of the hydrological cycle and those interrelationships directly influenced by soil and surface drainage improvements have been identified and a model constructed. It permits assessment of the effect of drainage improvement on the total discharge from a drained plot for a given precipitation input. Total discharge is composed of surface run-off and drain discharge.

Particular emphasis is placed on the soil moisture component, infiltration and percolation to the ground-water table. All components except the unsaturated zone are treated as lumped systems. The unsaturated zone is represented in the model by a stack of up to 50 layers. The moisture transfer between layers is calculated by a forward finite difference type of calculation based on the physical characteristics of the soil layers.

Suggested for inclusion in the report of:

Surface Water	☒	Continental Erosion	☐
Groundwater	☐	Remote Sensing and Data Transmission	☐
Snow and Ice	☐		

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K. Best	306-975-5512

Description of research

HYDROLOGY OF WETLANDS

The role of snow and rain in Prairie wetlands relates to the length and travel time of the hydrological circuits feeding a wet site. The shorter the circuit, the greater the vulnerability of the wetland to the variability of atmospheric precipitation. The wetland will show greater variability in size and yearly composition at the expense of sustainability. Prairie wetlands fed by longer circuits exhibit greater permanency, a more stable environment for animal life, and the least costly sites to manage as natural wetlands, but often at the risk of a greater salinisation potential, of conflicting uses by society, and of lower property value owing to its classification as "marginal land" for Prairie agriculture.

Suggested for inclusion in the report of:

Surface Water	☒	Continental Erosion	☐
Groundwater	☐	Remote Sensing and Data Transmission	☐
Snow and Ice	☐		

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Description of research

TRANSPORT OF SUSPENDED SEDIMENT

Parametric testing of various designs of suspended sediment samplers has been completed at Borden, on the North Saskatchewan River. Preliminary results indicate the profilers operate with a high efficiency in rivers. A new sampler has been designed for a one-month integration period. It has a glass liner for use in toxic chemical studies.

Suggested for inclusion in the report of:

- Surface Water ☒
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- Snow and Ice ☐
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- Remote Sensing and Data Transmission ☐

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Description of research

QUANTITY AND QUALITY OF IRRIGATION RETURN FLOW

Based on a two-year study (1986 and 1987), irrigating a soft white spring wheat (Triticum aestivum) by the corrugation method has resulted in 14.3% and 10.6%, respectively, of the applied irrigation water being returned as surface drainage water.

In 1986, 0.1% (0.12 kg/ha) of the applied nitrogen and 0.12% (0.07 kg/ha) of the applied phosphorus was lost to surface drainage water. In comparison, 0.07% (0.10 kg/ha) of the applied nitrogen and 0.79% (0.22 kg/ha) of the applied phosphorus was lost in 1987.

With respect to the loss of applied herbicides, the maximum concentrations observed in 1986 were 4.3 ppb Dicamba and 10.7 ppb MCPA compared to 4.7 ppb Dicamba, 12.9 ppb MCPA and 17.4 ppb Diclofop in 1987. The total loss of herbicides to drain water in 1986 was 0.12% (0.13 g/ha) of Dicamba and 0.11% (0.44 g/ha) of MCPA. In 1987, data showed 0.17% (0.18 g/ha) of Dicamba, 0.13% (0.56 g/ha) of MCPA and 0.18% (1.37 g.ha) of Diclofop. The levels of concentration are below the LC50 limits of 10 µg/L for aquatic invertebrates.

Suggested for inclusion in the report of:

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Description of research

ACID MINE DRAINAGE

Chemical and mineralogical analyses were performed on a suite of water and rock samples collected from an abandoned copper mine on Mount Washington, south-central Vancouver Island, B.C. The results, coupled with field observations, indicate that the precipitation of a green, arsenic-containing compound in the south pit of the mine is largely a result of mixing two waters of different composition.

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Description of research

PHYSICAL/BIOLOGICAL INTERACTIONS IN STREAM FLOW

An experiment was conducted in the experimental trough facility at Chase, B.C. The large (order of magnitude) differences noted in the accumulated algal biomass appear to be due solely to differences in the physical flow regimes.

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Description of research

EXPERIMENTAL RIVERS RESEARCH (EXTRA)

Experiments conducted at Chase, B.C. during 1984-1986 have conclusively established that the growth rates of periphytic diatoms in the Thompson River saturate at very low phosphate concentrations (<1 ppb). Long-term algal biomass accumulation experiments have shown that the maximum biomass of algae attained in flowing water also shows saturation kinetics. However, the concentrations of phosphate required to saturate the maximum sustainable standing crop of algae are considerably higher (about 5-25 ppb) than those which saturate cellular growth rate. The shape of the biomass saturation curve means that a one-for-one, removal of phosphorus vs. reduction of algae, is not expected. A simple analysis indicates that a 50% reduction in phosphorus from mill effluent would result in less than 20% improvement downstream: for a 60% reduction in algal biomass, at least 90% of the available soluble phosphorus in the effluent would have to be removed. This suggests that additional efforts to control downstream algae by removing phosphorus from the pulp-mill effluent would be relatively ineffective. Decline of the "nuisance" levels of algae reported in the 1970's suggest that additional control measures may not even be warranted.

Suggested for inclusion in the report of:

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Description of research

BIOGEOCHEMISTRY IN FRESHWATER ENVIRONMENTS

Clay minerals, Fe and Mn oxides, and humic matter ("colloids") have complex and often dramatic effects on the microbial methylation and demethylation of mercury (Hg), and on other microbial activities, in lake sediments. The colloids can strongly inhibit or stimulate the Hg transformations, have little or no effect, or alternate in their effects. They probably alter the species composition of the microbial community and affect the course of ecological succession, upsetting the dynamic balance between methylation and demethylation and causing alternate increases and decreases in methyl mercury (Ch_3Hg^+) levels along with changes in other indicators of microbial activity (CO_2 and CH_4 production and Eh). The role of clay is critically dependent on surface coatings. Humic matter in solution tends to stimulate methylation; but humic coatings on clay impede methylation and foster demethylation. The effects of natural colloids on Hg speciation are vitally important but variable, inconsistent, and not altogether predictable.

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Description of research

TOXIC CHEMICAL EFFECTS ON FRESHWATER ECOSYSTEMS

Morphological deformities in chironomid larvae are being documented for the assessment of long-term chronic effects of contaminants on aquatic systems. These insect larvae possess a number of advantages as indicator organisms, including exposure to contaminant burdens in situ and the provision of a permanent record for assessment both as prepared specimens of contemporary communities and as specimens preserved in the sedimentary fossil record.

Emphasis is being placed on developing the tools necessary for evaluating and interpreting morphological responses. Operational techniques for assessing deformities in Chironomus and Procladius larvae are well advanced and information on deformities in other genera, such as Cryptochironomus, Cryptotendipes, Dicrotendipes, Parachironomus, Paralauterborniella, Polypedilum, Paratendipes, Phaenopsectra, Psectrocladius, Coelotanypus, Clinotanypus, and some members of the Tanytarsini are being developed as new field sites are analysed. Development of these evaluation techniques has reached the point where the various hypotheses on which the use of morphological deformities are based can be tested under experimental conditions and in different field situations.

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S.C. Bigras	306-975-5753

Description of research

MACKENZIE DELTA HYDROLOGY

The flooding regime and sill elevation of lakes in an area near Inuvik, N.W.T. was analysed using 12 to 25 years of Mackenzie River East Channel water level data. The timing of the spring rise in water levels is very consistent; peak levels occur on June 3 ±4 days. Because the magnitude of the spring flood varies greatly from year to year, only 67% of lakes in the study area flood annually in the spring. The remaining lakes have a flood frequency >1 and <4 years. By late summer water levels drop, cutting off approximately 88% of lakes from the Mackenzie River.

Break-up in the Mackenzie Delta, N.W.T. was monitored from 1981 to 1987. Thermal break-ups occurred in six of the seven years; a mechanical break-up occurred in 1982. The location of frequent ice jams in the Delta, as well as their formation, composition, and growth, and the backwater build-up and flow diversion patterns which result have all been documented.

Water in the Delta was analysed for temperature, conductivity, pH, turbidity and ionic concentrations of calcium and magnesium. The ecology of the Delta lakes is likely quite dependent of the replenishment of minerals during the the flooding of lakes and channels in the spring.

Suggested for inclusion in the report of:

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GROUND

WATER

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Description of research

FACILITY FOR INDOOR AQUIFER TESTING (FIAT)

The construction phase of the Facility for Indoor Aquifer Testing (FIAT) has been completed and it is now operational. It consists of five major subsystems: the tank body, solid/liquid sampling ports, soil moisture/ground water collection system, precipitation simulator, and the drain/ground-water table manipulation system. Preliminary tests, using de-ionised water, indicate that all systems are functioning and water samples can be retrieved from all depths. The initial geochemical results show a concentration profile developing which can be moved within the soil column by adjusting precipitation application rates and ground-water pumping rates. Preliminary tracer experiments show that the FIAT's instrumentation functioned well and performed as designed.

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Description of research

GROUND-WATER PESTICIDES STUDIES IN WESTERN CANADA

The results of two ground-water pesticide surveys carried out on a study area in the Abbotsford-Clearbrook area of southwestern British Columbia show that some pesticide contamination of ground water has occurred in a permeable unconfined aquifer.

The data indicate that small amounts of organophosphorus, organonitrogen, and organochlorine compounds can leach through the unsaturated, or vadose zone, and migrate toward domestic supply wells.

The British Columbia study shows that further research is needed to determine whether or not ground-water pesticide contamination in hydrogeologically vulnerable aquifers is a common occurrence in all agricultural areas of the country.

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Description of research

CONTAMINANT TRANSPORT IN LANDFILLS

A specialised, double-ring permeameter system has been designed for studying the interaction of landfill leachate with fine-grained soil samples suitable for use as barrier material. To permit chemical analysis of the leachate, all surfaces which contact the liquid are either Teflon or stainless steel. The system includes four independent permeameters and the ancillary equipment to support them. Arrangements have been made with the cities of Regina and Saskatoon to use their landfill sites.

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A. Vandenberg — 306-975-5746

Description of research

GROUND-WATER CONTAMINANT MODELLING

A digital model has been constructed for the simulation of the vertical movement of soil moisture through an unsaturated bed of Atmospheric Fluidised Bed Combustion (AFBC) solid waste, underlain and overlain by sandy soil. The model is based on a finite difference solution to Richard's equation and features:

1) an iterative routine for the calculation of flow between adjacent elements, when the elements are soil-physically dissimilar, and
2) a self-adjusting time step.

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Researcher(s)

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Description of research

GROUND-WATER USE AND CONTAMINATION IN CANADA

Ground water is not as widely used in Canada as surface water but is a significant source of water:

- approximately 1.46 billion m^3 of ground water were used in 1981.
- the municipal sector uses most: some 38% of all municipalities relied entirely or partially on ground water and about 26% of the population use it for their domestic water supply.
- ground-water use (as % of total water use) by sector is rural (82%), agricultural (13%), mining (12%), municipal (9%), and industrial ($\leq$1%).
- it accounts for over 60% of agricultural use east of the Manitoba-Saskatchewan border: approximately 87% for livestock, 3% for irrigation and almost all of the water used in fish farming.
- Prince Edward Island is almost completely dependent upon ground water.

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Description of research

LRTAP AND GROUND WATER, 1988/89

Investigations into the modification of the effects of acid precipitation by water-mineral interactions were continued at the Turkey Lakes Watershed, Ontario. The ground-water flow system has been divided into: a rapid flow in the surficial, highly permeable zone, characterised by low carbonate content and short residence time; and, slow flow in the deeper, less permeable zone, with higher carbonate content and longer residence time. Water chemistry in the former is largely determined by precipitation chemistry, in the latter by the buffering effect of the soil.

In the shallow regime, short-term pH depressions are observed in response to acid loadings such as from spring melt. The higher concentration of K^+ may be due to increased weathering of aluminum-silicate minerals, especially K-feldspar, during precipitation events. The trace carbonates in the soil cannot offset the increased acidity. The surficial sediments (0-20 cm) were depleted in K-feldspar but had significant aluminum-silicate alteration products. Deeper sediments (20-40 cm) had more K-feldspar. Equilibrium speciation studies using WATEQ suggest increasing saturation of the aluminum-silicate and carbonate minerals with depth.

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SNOW

AND

ICE

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Description of research

SNOW MANAGEMENT AND SNOWMELT INFILTRATION

The feasibility of stubble cropping can be improved if tall stubble strips are used for trapping snow. The average advantage in conserved soil water for tall compared to short stubble was 12.7 mm; 25% of that usually conserved by summerfallow. The economic benefit of snow trapping averaged 15-22 $/ha in dry years and 5-7 $/ha in years with average rainfall. There was no benefit in wet years. Getting the meltwater to enter the soil is still a major problem. Subsoiling to 25 cm or deeper was performed to increase infiltration. When snow management practices resulted in an appreciable snowpack, subsoiling produced over-winter soil-water gains which were two-to-four times those with conventional short stubble and no subsoiling. The field sites are located at Richlea, Kerrobert, Saskatoon and Swift Current.

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Description of research

SNOWMELT RUN-OFF IN PERMAFROST BASINS

A field study of snow-melt run-off was carried out in the Mackenzie Delta, N.W.T., and near Resolute Bay, N.W.T. The strong negative soil heat flux delayed the arrival of melt water at the snowcover base. The wetting front breaks into well-defined flow fingers which allow water to move rapidly into the snow pack without wetting the entire snow cover. If the snow is cold enough, the water will freeze making these features easy to locate. They provide an excellent method to study the natural movement of water into the dry snowcover. Field work has provided information on the freqency of flow-finger occurrence, their relationship to premelt strata, and the effect of initial snow-pack properties. Once melt water reached the snowcover base, most infiltrated the soil. Even though the soil was below 0°C, only a small portion of the melt water which infiltrated the active layer refroze. As a result, the soil warming was not as large as would be expected if all the melt water had refrozen. The large soil infiltration also limits snow-melt run-off, which has important implications to the hydrology of lakes in the Mackenzie Delta.

Suggested for inclusion in the report of:

Surface Water	☐	Continental Erosion	☐
Groundwater	☐	Remote Sensing and Data Transmission	☐
Snow and Ice	☒		

NOTE: Water Quality and Water Resource Systems interests should be sent to one of these five correspondents.

CANADIAN GEOPHYSICAL BULLETIN

HYDROLOGY RESEARCH IN CANADA

1988

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Description of research

SNOWMELT RUN-OFF MODEL FOR NORTHERN ENVIRONMENTS

Five models have been evaluated - CEQUEAU (Institut national de recherche scientifique), SSARR (Streamflow Synthesis and Reservoir Regulation), TANK (Japanese National Disaster Prevention Center) NWSRFS (National Weather Service River Forecast System) and HSP-F (Hydrologic Simulation Program-F). In their present form it is unlikely that any will give reliable predictions of snowmelt run-off in Arctic environments without either extensive calibration of model parameters or major modifications or revisions to the simulation routines. The HYDROTEL model (Université du Québec) is also being investigated as a "base" model for the project.

A field site on the Norman Wells - Zama pipeline route in the headwaters of the Petitot River is under consideration. It appears to be an ideal location because it is currently experiencing the effects of climate change and also represents terrain which contributes low-elevation run-off to the river ice break-up/flood wave on the Liard River.

Suggested for inclusion in the report of:

- Surface Water ☐
- Groundwater ☐
- Snow and Ice ☒
- Continental Erosion ☐
- Remote Sensing and Data Transmission ☐

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Description of research

REMOTE SENSING, DOMAIN BASIN, MANITOBA

Ground-truth measurements of snowfall, air temperature and streamflow were obtained for six different target areas in Manitoba, Canada. Snowpack development was simulated for each target and compared with emitted microwaves. Air photos of spring flooding were obtained for the clay plain target and flooding was monitored using NOAA IR images. The microwave brightness difference between 37 and 18 GHz became increasingly negative as the cold snowpack increased from 2 to 200 mm water equivalent. By contrast, flooding from snowmelt produced a positive brightness difference when air temperature was above 0°C, which decreased over time as meltwater receded from the targets.

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Description of research

SNOW PROPERTIES

The calibration of a capacitive cell for measuring snow liquid water was studied using 251 samples, with liquid water measured independently by acid dilution. A nonlinear model with high goodness-of-fit to the data was derived from physical assumptions.

Refinements to the International Snow Classification (ISC) have been proposed based on based on crystal, rather than grain, morphology. The classification was extended to include terms already in the ISC, but seldom used systematically, emphasising the distinction between morphological and process-oriented concepts. An index of mean grain size has been described.

The snow research laboratory at Sunshine was closed in 1988. Studies in 1989 will be directed improving the interpretation of remote sensing signals from Prairie snow covers.

Suggested for inclusion in the report of:

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Groundwater	☐	Remote Sensing and Data Transmission	☐
Snow and Ice	☒		

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M.N. Demuth	306-975-5754
S. Fogarasi	306-975-5758

Description of research

PROXY CLIMATE DATA FROM ICE CORE

A significant positive correlation (teleconnection) has been found between the annual net mass balance time series (1900-1980) from Mount Logan, Y.T. and the areal mean of the November-March precipitation from the Steppe region of the central U.S.S.R. Teleconnections have also been found between the Mount Logan time series and series for the Canadian Prairies and Japan between 1900 and 1987. Stable isotope data indicate that "isotopic seasons" are generally phase lagged with respect to calendar seasons. They appear to be correlated with SSTs and ocean heat transfer curves as well as the position of the Aleutian Low rather than with air temperature or the temperature difference between the ocean surface and the core site. A preliminary time series analysis of 250 years of data shows spectral power at ENSO frequency at ~11 years and ~21 years.

An improved, shallow, ice-borehole logging system has been developed. It is capable of logging dry boreholes up to 200-metres deep and may be easily transported and assembled by its two operators. Modifications have been made to the Canadian Rufli-Rand core drill by incorporating an hydraulic winch/control system.

Suggested for inclusion in the report of:

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- Groundwater ☐
- Snow and Ice ☒
- Continental Erosion ☐
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Description of research

GLACIOLOGICAL INVESTIGATIONS OF PEYTO GLACIER, ALBERTA

The mass balance of Peyto Glacier in 1986/87 and 1987/88 were once again negative. Peyto Creek has been gauged during the winter months and the data will be used to construct the winter hydrograph. D.S. Munro (University of Toronto) continued his energy balance study. A thesis on water quality at Peyto Glacier was completed by C. Bradley under the direction of D.N. Collins (University of Manchester). Samples of preserved wood retrieved from in front of the glacier have been dated at 2900-3100 B.P. and further afield at 1140 and 505 B.P.

Suggested for inclusion in the report of:

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- Snow and Ice ☒
- Continental Erosion ☐
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O. Mokievsky-Zubok	

Description of research

INVESTIGATION OF COAST MOUNTAINS' GLACIERS

An international glaciology course under the direction of Dr Gunnar Østrem, was run at the end of July on Place Glacier.

A contract for the collection of winter-, summer- and net-mass balance data on Sentinel, Helm and Place Glaciers was awarded to G.K.C. Clarke of the University of British Columbia.

For the 1987 and 1988 balance years the specific mass changes (b_a) in water equivalent (H_2O), exhibited by the three glaciers, were as follows: Sentinel Glacier +0.15 and +0.45 m; Place Glacier -0.79 and -0.97 m; and, Helm Glacier -0.85 and -0.15 m. The equilibrium line altitudes, in m a.s.l., were 1875 and 1845, 2310 and 2310, and 2030 and 2100 respectively.

In collaboration with B.C. Hydro, a glacier mass-balance network was re-established on the Tiedemann and Bench Glaciers in the Homathko River basin and winter balance measurements were made in the second half of May.

Suggested for inclusion in the report of:

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Groundwater	☐	Remote Sensing and Data Transmission	☐
Snow and Ice	☒		

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Description of research

THREE-DIMENSIONAL DISTRIBUTION OF PERMAFROST

Field work is progressing at one upland and one peat and spruce-bog site in northern Alberta. Preliminary geophysical profiles obtained in August suggest that E.M. (electro-magnetic) surveying is an excellent method for detecting permafrost at this site; providing the capability of mapping the lateral distribution of frozen ground at different times of the year.

Suggested for inclusion in the report of:

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- Groundwater ☐
- Snow and Ice ☒
- Continental Erosion ☐
- Remote Sensing and Data Transmission ☐

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J. Kwong — 306-975-4719

Description of research

LABORATORY STUDIES OF MASS AND HEAT TRANSPORT

Two pieces of apparatus have been designed and constructed. The soil/water freezing apparatus facilitates controlled axial freezing of a soil/water mixture. The frozen soil/water test apparatus will be used to study the effects of thermal and chemical perturbations on frozen soil.

Suggested for inclusion in the report of:

- Surface Water ☐
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- Snow and Ice ☒
- Continental Erosion ☐
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J. Kwong — 306-975-4719

Description of research

THE THERMAL REGIME IN A PERMAFROST ENVIRONMENT

Two sites in northern Alberta have been selected for detailed study. The thermal regime at the Mount Watt site appears to be in equilibrium with the current climatic conditions and is very sensitive to variations in the local environment. Scattered permafrost occurrences in the Meander River site, however, could be relict.

A re-examination of occurrences of frozen ground along the Mackenzie Highway from Keg River, Alberta to Hay River, N.W.T. indicated a local northward retreat of the fringe permafrost zone by as much as 120 km in the past 25 years. To explain the disappearance of frozen ground, climatic records of the region during the past four decades were analyzed. Whereas a weak warming trend is apparent from the analysis of air temperature data, a detailed explanation of the degradation of permafrost in the region has to await analyses of other contributing parameters like vegetation cover, economic development in region, etc.

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Description of research

RIVER-ICE BREAK-UP ADVANCE

During melt periods, river ice can experience significant changes in strength that partly determine the severity of break-up conditions, but in situ strength tests are relatively scarce. The borehole jack is a field-portable hydraulic indentation device which enables the in situ testing of the confined-compressive strength of ice. It was used to determine changes in ice strength during an 18 day pre-break-up melt period on the Liard River, N.W.T., Canada. Measurements were also made of the river-ice energy balance. Strength, measured by ultimate platen pressure, decreased by approximately 50% at a rate of 0.4 MPa/d or 0.07-0.08 MPa/MJ m^{-2} d^{-1}.

Although a porosity of 0.4 is commonly assumed in the case of breakup jams, there had been no field verification of this value. On April 29, 1983, an ice jam developed at the confluence of the Liard and Mackenzie Rivers and increased to a maximum length of approximately 22.8 km by May 4. Ice jam porosity was calculated by comparing the volume of ice melted within the jam to measured changes in the total (ice and water) jam volume.

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S.C. Bigras	306-975-5753

Description of research

MACKENZIE DELTA HYDROLOGY

The flooding regime and sill elevation of lakes in an area near Inuvik, N.W.T. was analysed using 12 to 25 years of Mackenzie River East Channel water level data. The timing of the spring rise in water levels is very consistent; peak levels occur on June 3 ±4 days. Because the magnitude of the spring flood varies greatly from year to year, only 67% of lakes in the study area flood annually in the spring. The remaining lakes have a flood frequency >1 and <4 years. By late summer water levels drop, cutting off approximately 88% of lakes from the Mackenzie River.

Break-up in the Mackenzie Delta, N.W.T. was monitored from 1981 to 1987. Thermal break-ups occurred in six of the seven years; a mechanical break-up occurred in 1982. The location of frequent ice jams in the Delta, as well as their formation, composition, and growth, and the backwater build-up and flow diversion patterns which result have all been documented.

Water in the Delta was analysed for temperature, conductivity, pH, turbidity and ionic concentrations of calcium and magnesium. The ecology of the Delta lakes is likely quite dependent of the replenishment of minerals during the the flooding of lakes and channels in the spring.

Suggested for inclusion in the report of:

Surface Water	☒	Continental Erosion	☐
Groundwater	☐	Remote Sensing and Data Transmission	☐
Snow and Ice	☒		

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REMOTE SENSING

AND

DATA TRANSMISSION

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